UNIVERSITI PUTRA MALAYSIA

NONLINEAR FINITE ELEMENT MODELING OF BURIED CONDUIT STRUCTURE

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FK 2005 86

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December 2005

NONLINEAR FINITE ELEMENT MODELING OF BURIED CONDUIT STRUCTURE

By

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A Project Report Submitted in Partial Fulfillment of The Requirement For The Degree of Master of Science In Structure Engineering And Construction In The Department of Civil Engineering

University Putra Malaysia

Serdang Selngor Malaysia

December 2005

ACKNOWLEDGEMENT

The author deeply grateful to Dr. Jamalodin Noorzaei, Associete Professor in Civil Engineering Department of University Putra Malaysia for his guidance and assistant in the process of modeling work. His assistant in solving the problem during calibration of the finite element model and the theory of soil nonlinearity is highly appreciated.

The author also would like to thank Dr. Mohd Saleh Jafaar, Head of Civil engineering Department and Dr. Waleed A. M Thanoon, Civil Engineering Department who have fully support on the completion of the project and master course.

Then, the author also would like to thank his family, especially his loving wife Aliza Abdullah and all his kids for their fully support in completion of his Master Degree Program.

Lastly, the author would like to thank his company manager Ir. Mohd Taha Abdul Wahab, his friend Mr. Aeid Ali and Mr Thevaneyan David for their support in his master course

ABSTRACT

Basically, the purposes of buried conduit structures are to carry water in water supply system, to carry wastewater or storm water and also for conducting small streams or drains under embankments. Buried conduit structures such as buried pipes, culverts and arches are generally designed to resist the load of overlaying soil, traffic load and also the internal fluid pressure.

In this project, the selected buried conduit structure was a steel pipe. The analysis was carried out by Finite Element Method which was written in high level programming language, FOTRAN, environment. The models were carried out in linear and nonlinear analysis for various load cases. The comparison result of linear and nonlinear analysis were carried out, in order to study the behavior of steel pipe and surrounding soil react to the load cases. In this study also, all the models were simulated by taking into account the effect of interface element.

In addition, the classical method in designing the steel pipe, previous study on buried pipe, theory of finite element method and the theory of nonlinear elastic soil model were also presented.

APROVAL

I CERTIFY THAT AN examination Committee has met on 26 November 2005 to conduct the final examination of Razali Ahmad on his Master of Science (Structural Engineering and Construction) thesis entitle “ Nonlinear Finite Element Modeling of Buried Conduit Structures”. The committee recommended that the candidate be awarded the relevant master degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citation that have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any others degree at UPM at other institutions.

Razali bin Ahmad

Date :

CONTENT		PAGE

ABSTRACT		i
ACKNOWLEDGEMENT		ii
APROVAL		iii
DECLARATION		iv
LIST OF TABLE		v
LIST OF FIGURE		vi - xiii
1.0	**INTRODUCTION**	
1.1	Introduction	1
1.2	Application of Buried Steel Pipe	2-12
1.3	Objective	13
1.4	Scope of Study	13 – 14
2.0	**LITERATURE REVIEW**	
2.1	Introduction	15 – 26
2.2	Earlier Work	27 – 31
2.3	Classical Method	31 - 33
2.4	Finite Element Method	34 – 39
2.5	Loading of The Buried Pipe	40 – 44
2.6	Soil-Structure Interaction	44 - 60
2.7	Conclusion Remark	60

3.0	**METHODOLOGY**	
3.1	Introduction	61
3.2	Classical Method	62 – 77
3.3	Numerical Modeling	77 – 105
3.4	Mesh Refinement	106 - 113
3.5	Programming Aspect	114 – 121
3.6	Conclusion Remark	122
4.0	**NONLINEAR ELASTIC SOIL MODEL**	
4.1	Introduction	123 – 128
4.2	Procedure In Evaluation The Soil Parameter	128
4.3	Evaluation The Soil Parameter In Selected Soil	129 - 134
4.4	Conclusion Remark	135
5.0	**ANALYSIS OF BURIED STEEL PIPE**	
5.1	Introduction	136
5.2	Problem Definition	136 – 137
5.3	Finite Element Mesh	137 – 140
5.4	Material	140
5.5	Modeling and Loading	140 – 143
5.6	Result and Discussion	143 – 151
6.0	**CONCLUSION AND RECOMMENDATION**	
6.1	Conclusion	152 – 153
6.2	Problem and Recommendation	153 - 154

REFERENCES

APPENDIX I

APPENDIX II

APPENDIX III

APPENDIX 1
(CLASSICAL METHOD)

APPENDIX II
(DATA INPUT)

APPENDIX III
(TEST MODEL)

LIST OF TABLE

Table 2.1 : Soil Resistivity

Table 2.2 : The relative corrosivity of various soil

Table 3.1 : Peak Ground Velocity For Various Soil Condition

Table 3.2 : Displacement Result of The Present Study and Hinton & Owen (1977)

Table 3.3 ; Stress Result of The Present Study and Hinton & Owen (1977)

Table 4.1 : Stress-Strain Result For Test 1

Table 4.2 : Stress-Strain Result For Test2

Table 4.3 : Stress-Strain Result For Test3

Table 4.4 : The parameter of the soil nonlinearity in the modeling

Table 5.1 : The parameter of the Steel Pipe Properties and Interface Element

Table 5.2 : Result of fill/gravity load of linear analysis

Table 5.3 : Result of fill/gravity load of nonlinear analysis

Table 5.4 : Result of traffic load of linear analysis

Table 5.5 : Result of traffic load of nonlinear analysis

Table 5.6 : Result of internal load of linear analysis

Table 5.7 : Result of internal load of nonlinear analysis

Table 5.8 : Result of combination 1 of linear analysis

Table 5.9 : Result of combination 1 of nonlinear analysis

Table 5.10 : Result of combination 2 of linear analysis

Table 5.11 : Result of combination 2 of nonlinear analysis

LIST OF FIGURES

Figure 1.1 : Steel pipe is used for median drainage in Ontario Highway

Figure 1.2 : Corrugated steel pipe used as storm sewer

Figure 1. 3 : Corrugated steel pipe is used a long span structure

Figure 1.4 : Corrugated steel pipe is used as culvert bridge

Figure 1.5 : Corrugated steel pipe is used as detention system

Figure 1.6 : Corrugated steel pipe is used as fish migrating passage

Figure 1.7: Corrugated steel pipe is used as utility conduit

Figure 2.1 : Rigid Conduit

Figure 2.2 : Flexible Conduit

Figure 2.3 : Chronology of Finite Element (David, 1988)

Figure-2.4: Modes of deformation at interface (Zaman)

Figure 2.5 : Thin layer element (zaman)

Figure 2.6 : Soil-structure interaction for Structure-foundation system and retaining wall

Figure-2.7: Shear Behavior of Interface: (a) Direct Shear Test; (b) Deformation at Interface [Md. Musharraf-uz and Zaman, 1984]

Figure 3.1 : Compression Hoop Load

Figure 3.2 : Structure Radii, Hoop Load and Radii Soil Pressure for closed invert Structure

Figure-3.3: example of a one-dimensional system.

Figure-3.4: Different activities involved in creating versus using an FE program (David, 1988)

Figure-3.5: Quadrilateral family of elements

Figure-3.6: Natural coordinate system used in quadrilateral elements

Figure-3.7: Variation of shape function N_1 and N_2 over a quadrilateral element

Figure-3.8: Typical element

Figure-3.9: Interface in between 6-noded and 8-noded element

Figure-3.10: General three-dimensional body (Klaus-Jurgen Bathe)

Figure-3.11: Basic element types

Figure-3.12: Parabolic isoparametric element

Figure-3.13: Common methods of nodal constraints

Figure-3.14: Nodal force

Figure-3.15: resolution of pressure load into nodal forces

Figure-3.16: The increase of number element vs. to percentage of deflection error of a cantilever beam with a point load at 'A'

Figure-3.17: Deflection error with increasing of elements complexity

Figure-3.18: Deflection error vs. different types interpolation and number of element

Figure-3.19: Method of calculating the aspect ratio of triangle and quadrilateral

Figure-3.20: limit of internal angle

Figure-3.21: Limit of warping angle of element faces

Figure-3.23: Finite Element Program Organization

Figure-3.24: thick circular cylinder

Figure: 3.25 : Displacement Along x – direction

Figure: 3.26 : Displacement Along Y –Direction

Figure 3.27 : Actual Size of Pipe Model

Figure 3.28 : Stress in The Actual Pipe Model

Figure 4.1 : Hyperbolic Stress-Strain Behavior

Figure 4.2 : Strain/Dev.Stress Versus Strain of Soil BH14

Figure 4.3 : Initial Tangent Modulus (Ei) Versus Confining Pressure (σ_3)

Figure 5.1 : Finite Element Mesh

Figure 5.2 : HB Load applied on the model

Figure 5.3 : HB Load converted to point load on the model (Detail A)

Figure 5.4 : Internal Pressure applied in the model

Figure 5.5 : Displacement At Surface (Section A - A)

Figure 5.6: Displacement at 1.6 m below Ground Level (Section B - B)

Figure 5.7 : Displacement at Crown level (Section C - C)

Figure 5.8 : Displacement At Springline (Section D - D)

Figure 5.9 : Displacement At Bed Level (Section E - E)

Figure 5.10a & b: Displacement at Crown

Figure 5.11a & b : Displacement at Springline

Figure 5.12a : Depth Vs Sigma X (Section 1-1)

Figure 5.12b : Depth Vs Sigma Y (Section 1-1)

Figure 5.13a: Depth Vs Sigma X (Section 2-2)

Figure 5.13b: Depth Vs Sigma Y (Section 2-2)

Figure 5.14a: Depth Vs Sigma X (Section 3-3)

Figure 5.14b: Depth Vs Sigma Y (Section 3-3)

Figure 5.15a: Depth Vs Sigma X (Section 4 - 4)

Figure 5.15b: Depth Vs Sigma Y (Section 4 - 4)

Figure 5.16a : Depth Vs Sigma X (Section 5-5)

Figure 5.16b : Depth Vs Sigma Y (Section 5-5)

Figure 5.17 : Pipe X-Stress Vs Element

Figure 5.18 : Pipe Y-Stess Vs Element

Figure 5.19 : Pipe Shear Stress Vs Element

Figure 5.20 : Displacement At Surface (Section A - A)

Figure 5.21: Displacement at 1.6 m below Ground Level (Section B - B)

Figure 5.22 : Displacement at Crown level (Section C - C)

Figure 5.23 : Displacement At Springline (Section D - D)

Figure 5.24 : Displacement At Bed Level (Section E - E)

Figure 5.25a & b : Displacement at Crown

Figure 5.26a & b : Displacement at Springline

Figure 5.27a: Depth Vs Sigma X (Section 1-1)

Figure 5.27b: Depth Vs Sigma Y (Section 1-1)

Figure 5.28a: Depth Vs Sigma Y (Section 2-2)

Figure 5.28b: Depth Vs Sigma Y (Section 2-2)

Figure 5.29a : Depth Vs Sigma X (Section 3-3)

Figure 5.29b : Depth Vs Sigma Y (Section 3-3)

Figure 5.30a: Depth Vs Sigma X (Section 4 - 4)

Figure 5.30b: Depth Vs Sigma Y (Section 4 - 4)

Figure 5.31a: Depth Vs Sigma X (Section 5-5)

Figure 5.31b: Depth Vs Sigma Y (Section 5-5)

Figure 5.32 : Pipe X-Stress Vs Element

Figure 5.33 : Pipe Y-Stess Vs Element

Figure 5.34: Pipe Shear Stress Vs Element

Figure 5.35 : Displacement At Surface (Section A - A)

Figure 5.36: Displacement at 1.6 m below Ground Level (Section B - B)

Figure 5.37 : Displacement at Crown level (Section C - C)

Figure 5.38 : Displacement At Springline (Section D - D)

Figure 5.39 : Displacement At Bed Level (Section E - E)

Figure 5.40a & b: Displacement at Crown

Figure 5.41a & b: Displacement at Springline

Figure 5.42a : Depth Vs Sigma X (Section 1-1)

Figure 5.42b : Depth Vs Sigma Y (Section 1-1)

Figure 5.43a: Depth Vs Sigma X (Section 2-2)

Figure 5.43b: Depth Vs Sigma Y (Section 2-2)

Figure 5.44a: Depth Vs Sigma X (Section 3-3)

Figure 5.44b: Depth Vs Sigma Y (Section 3-3)

Figure 5.45a: Depth Vs Sigma X (Section 4 - 4)

Figure 5.45b: Depth Vs Sigma Y (Section 4 - 4)

Figure 5.46a : Depth Vs Sigma X (Section 5-5)

Figure 5.46b : Depth Vs Sigma Y (Section 5-5)

Figure 5.47 : Pipe X-Stress Vs Element

Figure 5.48 : Pipe Y-Stess Vs Element

Figure 5.49 : Pipe Shear Stress Vs Element

Figure 5.50: Displacement At Surface (Section A - A)

Figure 5.51 : Displacement at 1.6 m below Ground Level (Section B - B)

Figure 5.52 : Displacement at Crown level (Section C - C)

Figure 5.53: Displacement At Springline (Section D - D)

Figure 5.54: Displacement At Bed Level (Section E - E)

Figure 5.55a & b : Displacement at Crown

Figure 5.56a & b: Displacement at Springline

Figure 5.57a : Depth Vs Sigma X (Section 1-1)

Figure 5.57b : Depth Vs Sigma Y (Section 1-1)

Figure 5.58a: Depth Vs Sigma X (Section 2-2)

Figure 5.58b: Depth Vs Sigma Y (Section 2-2)

Figure 5.59a: Depth Vs Sigma X (Section 3-3)

Figure 5.59b: Depth Vs Sigma Y (Section 3-3)

Figure 5.60a: Depth Vs Sigma X (Section 4 - 4)

Figure 5.60b: Depth Vs Sigma Y (Section 4 - 4)

Figure 5.61a : Depth Vs Sigma X (Section 5-5)

Figure 5.61b : Depth Vs Sigma Y (Section 5-5)

Figure 5.62 : Pipe X-Stress Vs Element

Figure 5.63 : Pipe Y-Stess Vs Element

Figure 5.64 : Pipe Shear Stress Vs Element

Figure 5.65 : Displacement At Surface (Section A - A)

Figure 5.66: Displacement at 1.6 m below Ground Level (Section B - B)

Figure 5.67 : Displacement at Crown level (Section C - C)

Figure 5.68 : Displacement At Springline (Section D - D)

Figure 5.69 : Displacement At Bed Level (Section E - E)

Figure 5.70a & b: Displacement at Crown

Figure 5.71a & b : Displacement at Springline

Figure 5.72a : Depth Vs Sigma X (Section 1-1)

Figure 5.72b : Depth Vs Sigma Y (Section 1-1)

Figure 5.73a: Depth Vs Sigma X (Section 2-2)

Figure 5.73b: Depth Vs Sigma Y (Section 2-2)

Figure 5.74a: Depth Vs Sigma X (Section 3-3)

Figure 5.74b: Depth Vs Sigma Y (Section 3-3)

Figure 5.75a: Depth Vs Sigma X (Section 4 - 4)

Figure 5.75b: Depth Vs Sigma Y (Section 4 - 4)

Figure 5.76a : Depth Vs Sigma X (Section 5-5)

Figure 5.76b : Depth Vs Sigma Y (Section 5-5)

Figure 5.77 : Pipe X-Stress Vs Element

Figure 5.78 : Pipe Y-Stess Vs Element

Figure 5.79 : Pipe Shear Stress Vs Element

CHAPTER 1

INTRODUCTION

1.1 Introduction

Buried conduit structures system are commonly used to transport water, sewerage, oil, natural gas, electric power, telecommunication cables, transportation , etc . Since the pipelines carry materials essential to the support of life and maintenance of property they often referred to as "lifelines'"(M.O'Rourke and Lie,2000). Normally the top of the pipe is filled with earth. Basically, the purposes of buried conduit structures are to carry water in water supply system, to carry wastewater or storm water and also for conducting small streams or drains under embankments. Buried conduit structures such as buried pipes, culverts and arches are generally designed to resist the load of overlaying soil, traffic load and also the internal fluid pressure. In many instances, the variation of external soil and traffic loads on the pipelines shall be a minor effect if the pipe is not placed close to the surface.

The understanding of soil-structure interaction is very important to the analysis, design and performance of the buried structures, because buried structures alone cannot withstand or resist the loads to which they are subjected without the supporting strength of the surrounding soil in a complex interaction.

This soil-structure interaction will be affected by the properties of structure such as type of material, size and stiffness of that material. Beside that, the construction method, the way the backfill material placed and the existing of the external loading such as transportation load may take into account during the design state.

The characteristics of the interfaces between the structure and foundation may affect the response of the structure-foundation system when subjected to dynamic loadings such as the movement or settlement of soil.

1.2 Application of Buried Steel Pipe

The steel buried pipe is used widely in storm drainage, long span structure, corrugated steel box, storm water management and special water related issues. Generally, drainage facilities can be classified into three major types of construction; culvert, storm water and bridge.

The distinction between culvert and storm sewers is made mostly on the basis of length and types of inlets and outlets. A culvert is defined as an enclosed channel serving as a continuation or substitute for an open stream, where that stream meets an artificial barrier such as a roadway, embankment or leveee. A culvert may also be classified as a type of bridge. Normally, the rigid definition of bridge requires that the deck of the structure also be the roadway surface and simply an extension of the roadway. The use of corrugated steel pipe large diameter pipe arches, structural plate and corrugated steel box culvert have played a major role as replacements for deteriorated bridges and altered this conventional definition.

Figure 1.1 : Steel pipe is used for median drainage in Ontario Highway

Corrugated steel storm sewers have a service of over 100 years. The use of corrugated steel pipe for storm sewer has grown. The strength, flexibility, positive joints and installation economies of steel storm sewers are assured by the use of rational corrosion design criteria and readily available coating and lining. Steel storm sewers are also used to re-line failing sewers of all sizes, shapes and materials with a minimum reduction in waterway area.

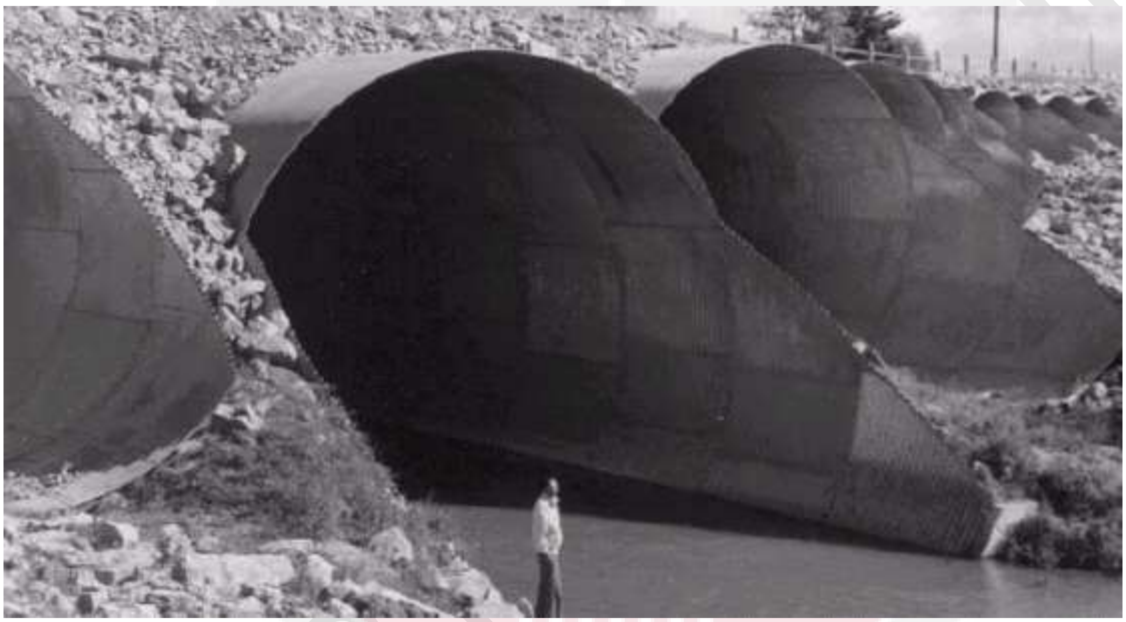

Figure 1.2 : Corrugated steel pipe used as storm sewer

The corrugated steel pipe also used to replace or rebuilt a secondary bridge which has a span less than 15 m in length. In the late 1960's, developments were made which involved adding longitudinal and circumferential stiffening members to the conventional 152 x 51 mm corrugation structural plate structures which permitted the use of larger sizes and increased permissible live and dead loads. This concept made it possible to achieve clear spans up to 18 m and clear areas up to approximately 100 m^2. With the introduction in Canada of 381 x 140 mm deep corrugated structural plate in the 1990's, clear spans increased to 23 m with clear areas of 157 m^2. Long span structures are particularly suited for relatively low, wide opening requirements. Depth of cover generally ranges from 0.3 to 30 m.

Design procedures covering these long span structures can be found in the Canadian Highway Bridge Design Code (CHBDC) and the latest editions of the AASHTO Standard Specifications for Highway Bridges, Section 12.7, and LRFD Bridge Design Specifications, Section 12.8.

Figure 1. 3 : Corrugated steel pipe is used a long span structure

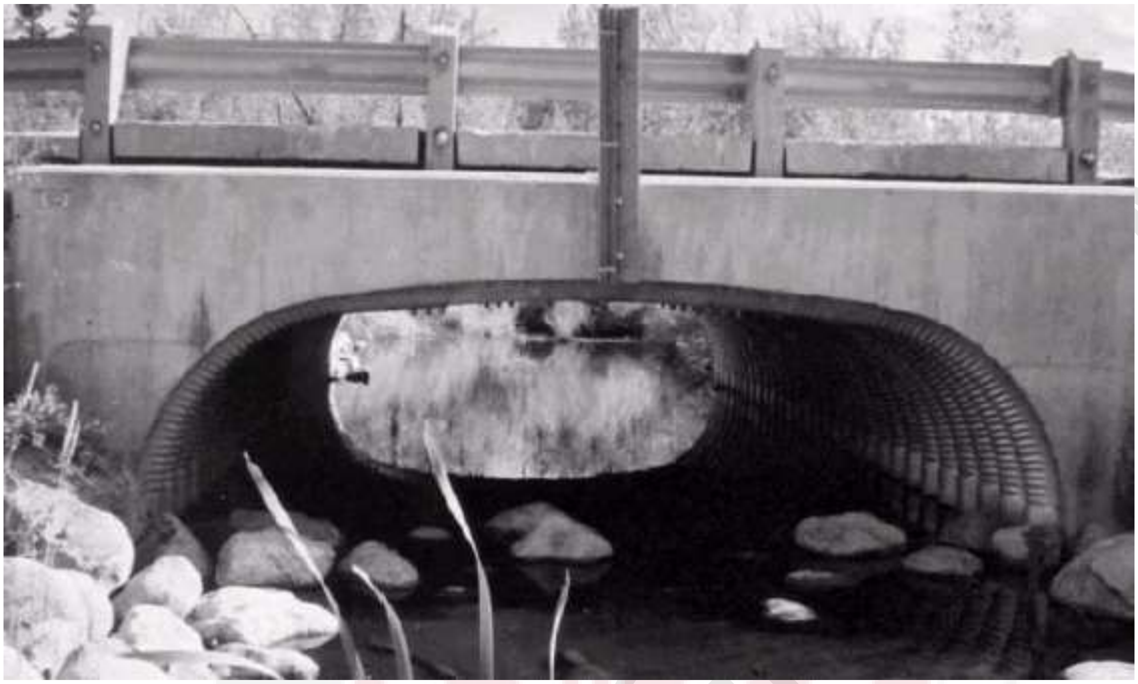

Figure 1.4 : Corrugated steel pipe is used as culvert bridge

The continuing spread of urbanization requires new drainage concepts to provide efficient and safe disposal of storm water runoff. Existing storm drains in most areas cannot handle the additional volume at peak flow times. Severe flood damage can occur without storm water management utilizing such tools as retention and detention systems.

Where storm water runoff has no outlet for disposal, a retention system is a viable solution. The storm water is deliberately collected and stored, then allowed to dissipate by infiltration into the ground. Additional benefits are the enhancement of the ground water resources and the filtration of storm water through percolation. The use of fully perforated corrugated steel pipe for recharge wells and linear pipes is a very cost effective way of disposing of excess storm water.

Where storm water runoff has an outlet that is restricted due to downstream use during peak flow periods, a detention system can be used. Temporary detention of storm water in corrugated steel pipe storage tanks can be most economical and reliable. Storm water is detained beyond the peak flow period and then systematically released into the downstream storm drain. The demand for zero increase in rate of runoff is very apparent in urban drainage design. Using corrugated steel pipe for detention and retention systems answers that need.

Figure 1.5 : Corrugated steel pipe is used as detention system

Soil erosion by water is a common and destructive force that plagues many engineering works. It makes unsightly gullies on roadways, cut slopes and embankments. It gouges out side ditches, fills culverts with sediment and is a costly nuisance. There are three basic ways of preventing erosion. The first is to treat the surface by paving, riprap, erosion-resistant turf, vines, or other vegetation. The second is to reduce the velocity of the water by means of ditch checks. The third is to intercept the water by means of inlets and convey it in corrugated steel flumes, pipe spillways, stream enclosures, or storm drains. Larger streams may be controlled by steel sheeting, jetties, or retaining walls. Corrugated steel pipe, with its long lengths, positive joints and flexibility to conform to shifting soil, provides a most dependable means of solving erosion problems.

Earth dams, levees and many other types of embankments require culverts or outlets for intercepted or impounded water. Corrugated steel pipes are particularly advantageous and have enviable records for this type of service Small dams are used extensively for soil conservation and to supply drinking water for livestock. Large dams may impound water for public supplies, irrigation, power, recreation, or navigation. All dams require some means, such as a drain pipe spillway, to handle normal overflow and prevent overtopping and possible washout. For emergency overflow, a turf covered ditch, or one lined with a corrugated steel flume, or chute is usually satisfactory. Soil conditions at these locations are seldom ideal. Hence strong, flexible pipes are needed to resist disjointing, settlement and infiltration of the surrounding soil.

In many sites, the need to accommodate migrating fish passage is an important consideration in culvert design. Transportation and drainage designers should seek early coordination with environmental, fish, and wildlife agencies Extensive experience has shown clearly that culverts can be designed to provide for fish passage. Design criteria for the specific fish species should be clarified during project development. Conversely, prevention of migration of rough fish or lampreys into upstream spawning grounds can also be accommodated, through the incorporation of suitable weirs or barriers into the culvert design. Several variations in design are possible to accommodate fish passage:

1. ***Open-Bottom Culverts*** - or arch-type culverts on spread footings retain the use of the natural streambed. This approach is favored in streams with rocky or semi-resistant channels. Selection of a wider-than-usual arch span also provides for maintenance of natural stream velocities during moderate flows.
2. ***Tailpond Control Weirs*** - have proven to be the most practical approach to meet a minimum water depth requirement in the culvert barrel. A series of shallow weirs, with a notch or small weir for low-flow passage, have proven extremely effective. Larger weirs

of more substantial design may require provision for separate fish ladder bypasses.

3. ***Oversized Culverts*** - limiting velocities may require the use of oversized culverts. Oversizing and depressing the culvert invert below the natural stream bed permits gravel and stone deposition, resulting in a nearly natural stream bed within the culvert. Numerous velocity profiles taken during floods indicate that wall and bed friction permit fish passage along the wall. In effect, the roughness of the steel barrel assists in fish passage.

4. ***Culverts with baffles*** attached to the invert - considerable recent laboratory and prototype research has indicated that baffles or spoilers can significantly aid fish passage.

5. ***Multiple barrel installations*** - have proven particularly effective in wide, shallow streams. One barrel can be specifically designed with weir plates inside the barrel to provide for fish passage. The use of baffles in the barrel. Structural plate pipe installation with fish baffles attached to invert. of a drainage structure is also useful at sites where energy dissipation may be desirable.

Figure 1.6 : Corrugated steel pipe is used as fish migrating passage

Power plants require vast amounts of cooling water. Structural plate steel pipes over 6 m in diameter have been used for water intakes. These lines are typically subaqueous, requiring special underwater construction by divers. Corrugated steel is especially suitable for this type of construction and has been used for such lines in the Great Lakes region. Thermal pollution is a major problem with discharge water from power plants. In large deep bodies of water, long discharge lines of structural plate pipe can carry the heated effluent to sufficient depth for dilution or tempering.

Steel conduits serve many practical purposes other than for drainage and sewers.

Some of these are:

- ***Underpasses*** or tunnels for safe movement of people, animals and vehicles.
- ***Materials handling*** in conveyor tunnels, aerial conduits or systems protected by conveyor covers; and storage bins for aggregates and other materials.
- ***Utility conduits*** for protecting pipe lines and cables; also entries, escapeways, ventilation overcasts and air ducts.

Figure 1.7: Corrugated steel pipe is used as utility conduit

1.3 Objective

The objective of this study is involves in analysis of buried steel pipe by classical method and finite element method. In the finite element method, the model will be modeled in linear and nonlinear analysis for a various loading conditions. The adopted soil condition in this study is based on the soil investigation report for the project of Immediate Action Plan Multimedia Super Corridor at Sg.Rasau/Air Hitam Selangor. The determination of soil nonlinear parameter is based on Duncan Method et al (1980). Furthermore, the applications of the buried steel pipe and past researches on the buried conduit structures were also presented in this study.

1.4 Scope of Study

Firstly, a brief on the type of buried conduits, construction method and durability of the steel pipe are presented in the literature review chapter. In the literature review chapter also, a brief on the code and manuals which are commonly used in analyzing and designing the buried pipe named as classical method. In addition, a past study and research on the buried conduit finite element modeling also presented by abstracting from internet, published journal and others thesis.

Secondly, in methodology chapter, it will brief on the classical method formulation in analyzing and designing the buried pipe. Then, a theory of finite element method , interface element and nonlinearity of soil parameter also presented in this chapter. Furthermore, it also presented the step of finite element modeling including the process of FOTRAN programme calibration.

In chapter 4, it will be presented the theory of nonlinear elastic soil model by Duncan et al (1980) and the procedure of evaluation the nonlinear soil parameter. In chapter 5, the study will discuss on the analysis of the selected buried steel pipe case, load case, the modeling results and the conclusion of the study will be presented chapter 6.

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